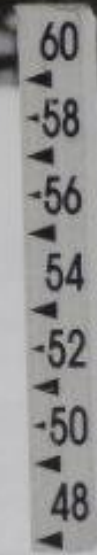


A Preliminary Examination of Snow to Liquid Ratios for Lake Effect Snow at NWS Marquette, MI

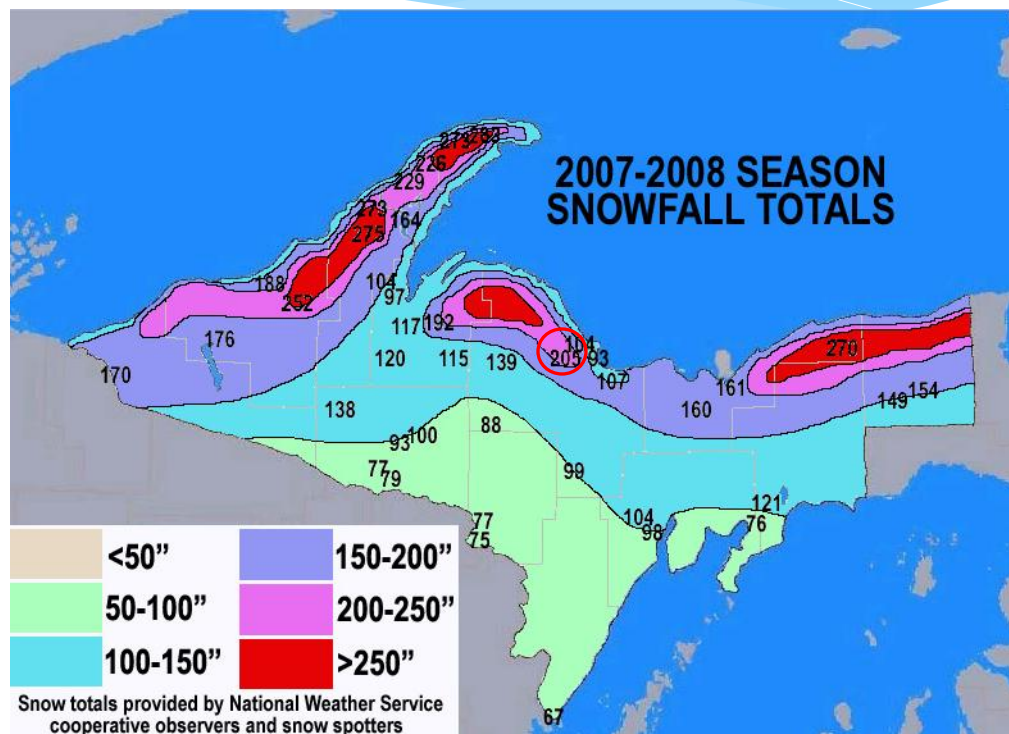


Mike Dutter
NOAA/NWS Marquette, MI
Great Lakes Operational Meteorology Workshop
Chicago, IL
14 March 2012

Photo by Megan Babich

Purpose

- * Lake Effect Snow significantly contributes to the annual snowfall across Upper Michigan
 - * Snowfall is normally tripled in the Lake Superior “Snowbelts” compared to interior sections
 - * In fact, LES amounts tend to be one of the (if not the most) significant winter forecast problem for the MQT office (and all Great Lakes Offices)
- * Previous SLR climatology studies have focused on overall SLR values:
 - * Have not focused on SLRs for specific “type” of snow.
 - * Most studies have used COOP data, which has a temporal resolution of 24 hr



Purpose

- * The main goal of this research is to look at SLR values for Lake Effect Snow using observational data from WFO MQT.
 - * Part of larger research to look at snow accumulation (specifically LES) forecasting across Upper Michigan.
- * Since we are forecasting snowfall at 6 hr intervals, it is important for forecasters to understand 6 hourly SLR values
- * The hope is that we can obtain baseline LES SLR values to use in our Snowfall and QPF forecasting

Deep snow at NWS Office, Negaunee MI

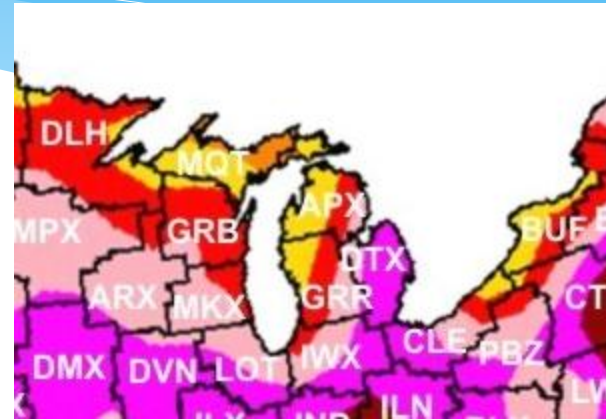
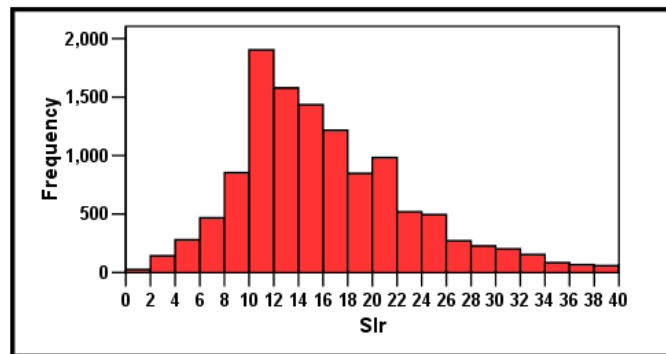
SLR Climatology from Baxter et al. (2005)

- * Looked at SLR climatology for the entire United States by National Weather Service WFO.
- * This study used COOP data to obtain a detailed SLR climatology for each WFO in the country.
- * Used 24 hr COOP data with snowfall amounts greater than 2 inches.
- * Although LES was mentioned in raising SLR values in the Great Lakes (especially in the middle of winter) little additional information was given regarding the impact of LES on the SLR values.

SLR Climatology for the Great Lakes and Histogram for WFO Marquette CWA (Baxter et al. 2005)

Marquette, MI

Avg SLR: 16.6
Standard Dev: 8.1
75th Percentile: 20.0
50th Percentile: 15.0
25th Percentile: 11.1



- * Currently serves as a “first guess” in SLR forecasting for snowfall events.
- * Forecast refinements are done based on microphysical techniques (Cobb and Walshtricher 2005) and other methods (Roebber et al. 2003, etc.)

Courtesy of CIPS - St. Louis University
Baxter et al (2005)

LES SLR Climatology -- Methodology

- * Look at 6 hourly snowfall and snow water equivalent observations at WFO MQT 2007-2011 with 1 inch or greater snowfall.
 - * Six hourly data may help to minimize pressure effects (settling) (Judson and Doeksen 2000)
 - * Plus, we forecast at 6 hourly intervals, so knowing 6 hourly SLR is important operationally.
- * Snowfall measurements were taken every 6 hours using a standard white snow board.
- * Snow Water Equivalent measurements were taken by using the standard NWS 8 inch rain gage (shielded to help reduce wind under-catch).

Methodology (Cataloging Events)

- * We then cataloged each event under one of three types:
 - * **Lake Effect (LES)**
 - * LES Bands as indicated by radar
 - * Little or no synoptic enhancement (moisture or dynamical)
 - * Lake Surface to 850mb temperature difference of at least 13C
 - * **Lake Enhanced**
 - * Lake Surface to 850mb temperature difference at least 8C
 - * Added system moisture and lift
 - * **System**
 - * Everything else

Methodology

- * After cataloging each event, a complete climatological analysis was done.
 - * Using additional information from WFO MQT Davis System (Temperature, Winds, etc.)
 - * An analysis was done for cases with at least 1 inch/6 hr and also for values of at least 2 in/6 hr. Roebber et al. (2003) and Baxter et al. (2005) used the 2 inch criteria for their studies.
- * In addition, a composite sounding was done for:
 - * All LES cases
 - * LES cases with SLR values 25th percentile or less
 - * LES cases with SLR values 75th percentile or more

Potential Errors

- * Since the official observing site is somewhat exposed, strong winds could cause error in several ways:
 - * Rain Gage under-catch (increased SLRs) despite having a shielded rain gage.
 - * Snow could be blown off snow board (increasing SLR).
 - * Compaction/Fracturing (lower SLRs).
 - * Blowing/Drifting may just cause erroneous measurement of snow.
- * Melting is not likely a concern given that nearly all temperatures during LES events were well below freezing.
 - * Liquid precipitation not a concern either, as there was no rain reported during any LES type event.

Results



Overview

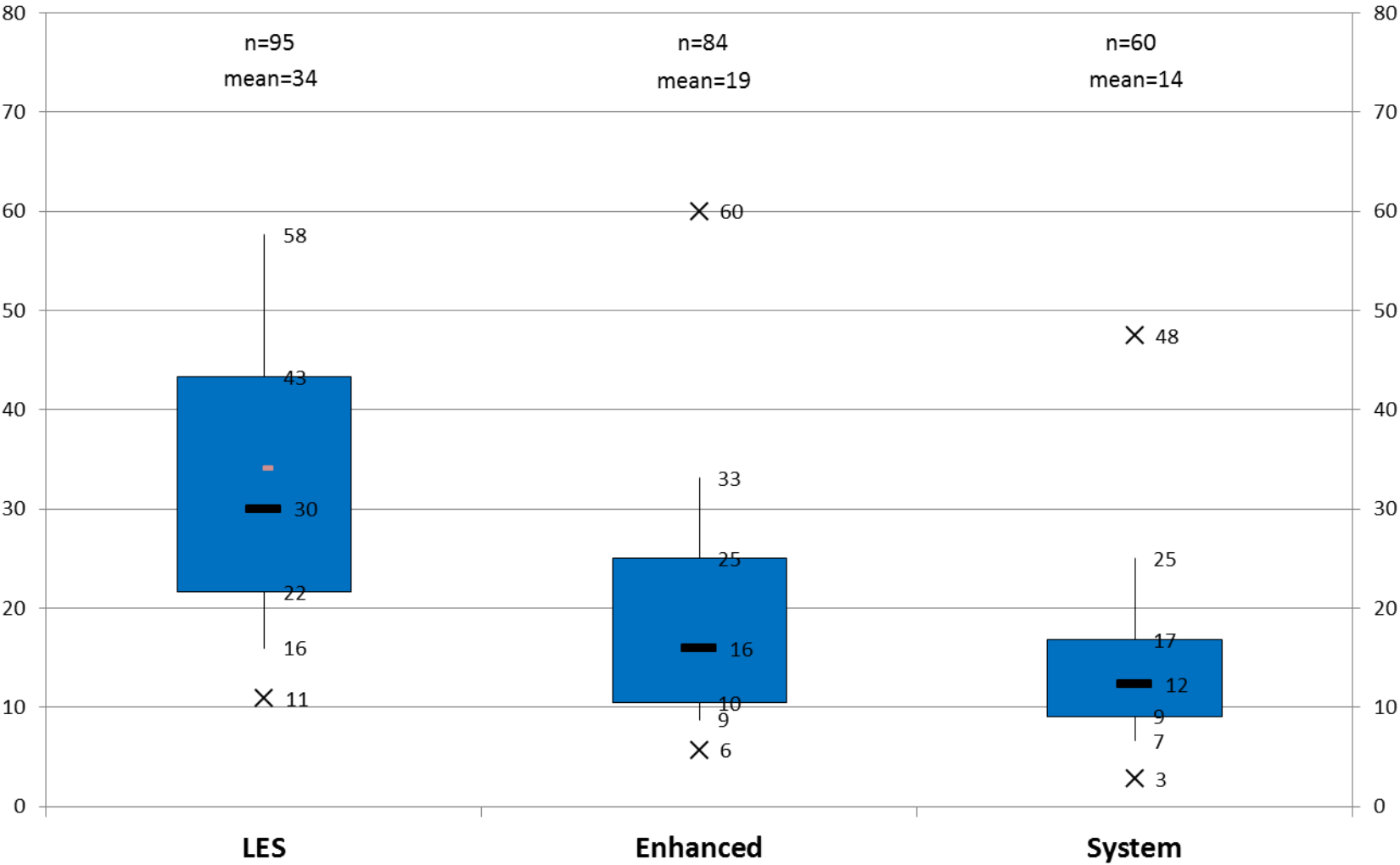
- * As expected, LES SLRs were significantly higher than Enhanced or System snowfall.
- * Out of 239 total cases with snow 1 in or greater, 95 were identified as pure LES cases.
 - * 84 were Enhanced, and 60 were System snowfall



Snow to Liquid Ratios (SLR) for NWS Marquette for Lake Effect, Lake Enhanced and System Snowfalls at least 1in/6hr



Solid Bar -- Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)

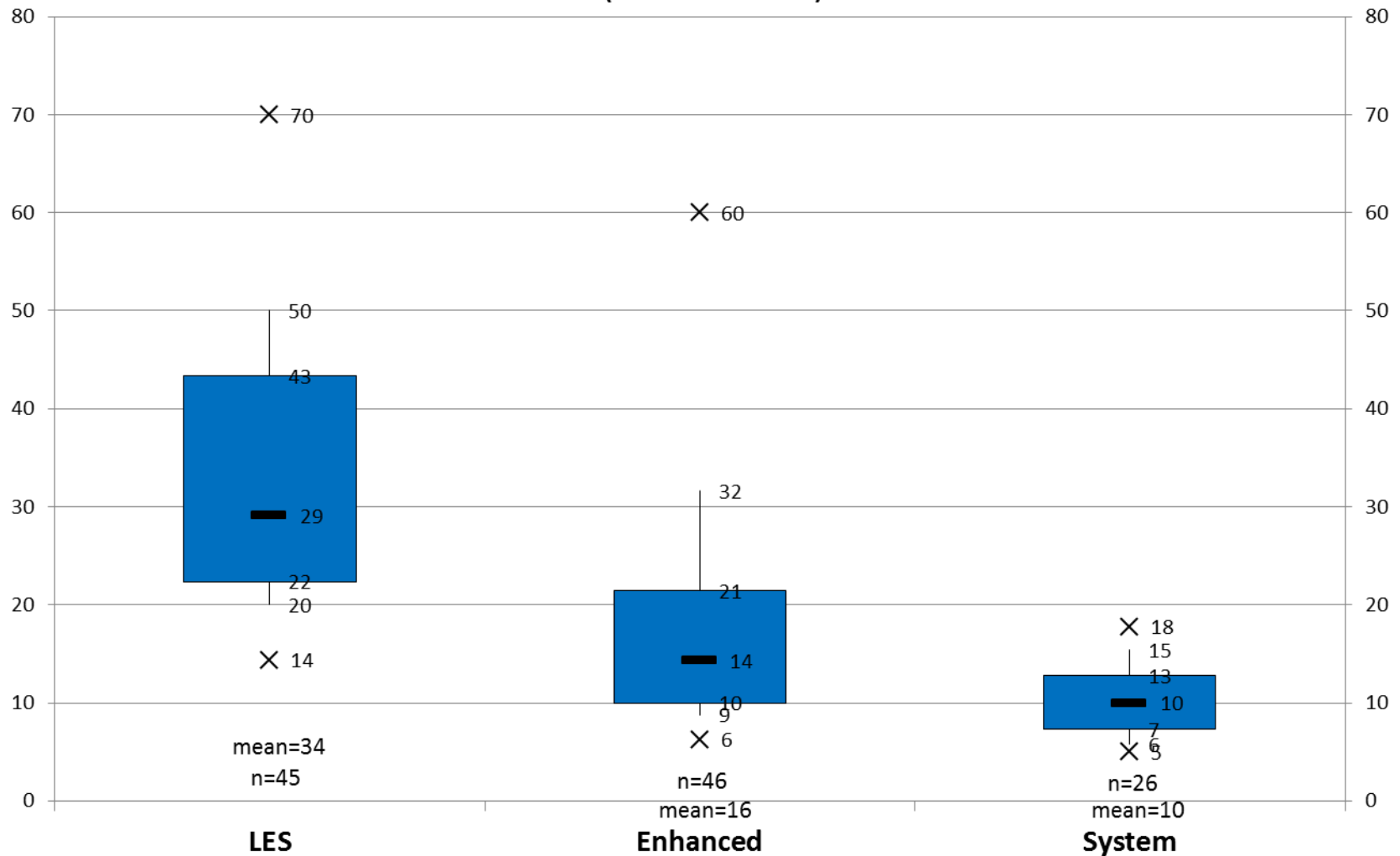




Snow to Liquid Ratios (SLR) for NWS Marquette for Lake Effect, Lake Enhanced and System Snowfalls above 2in/6hr



Solid Bar -- Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)

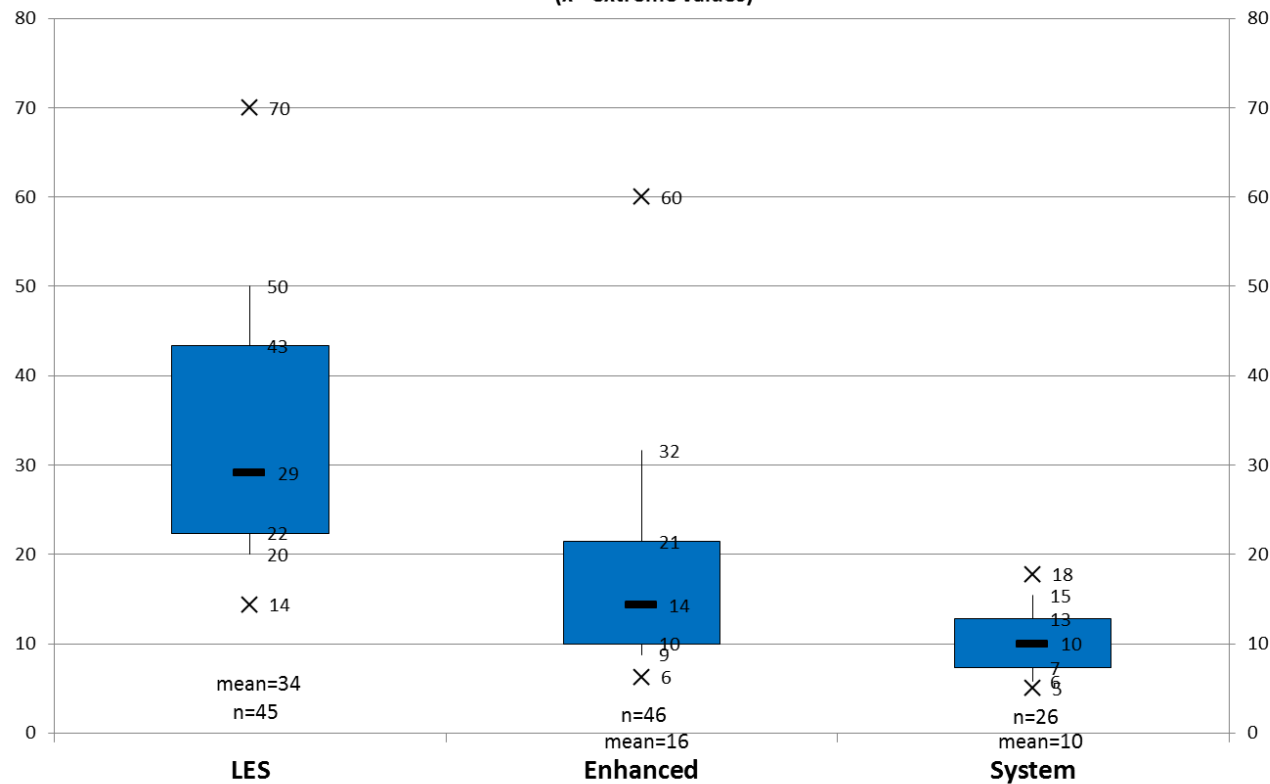




Snow to Liquid Ratios (SLR) for NWS Marquette for Lake Effect, Lake Enhanced and System Snowfalls above 2in/6hr



Solid Bar -- Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)



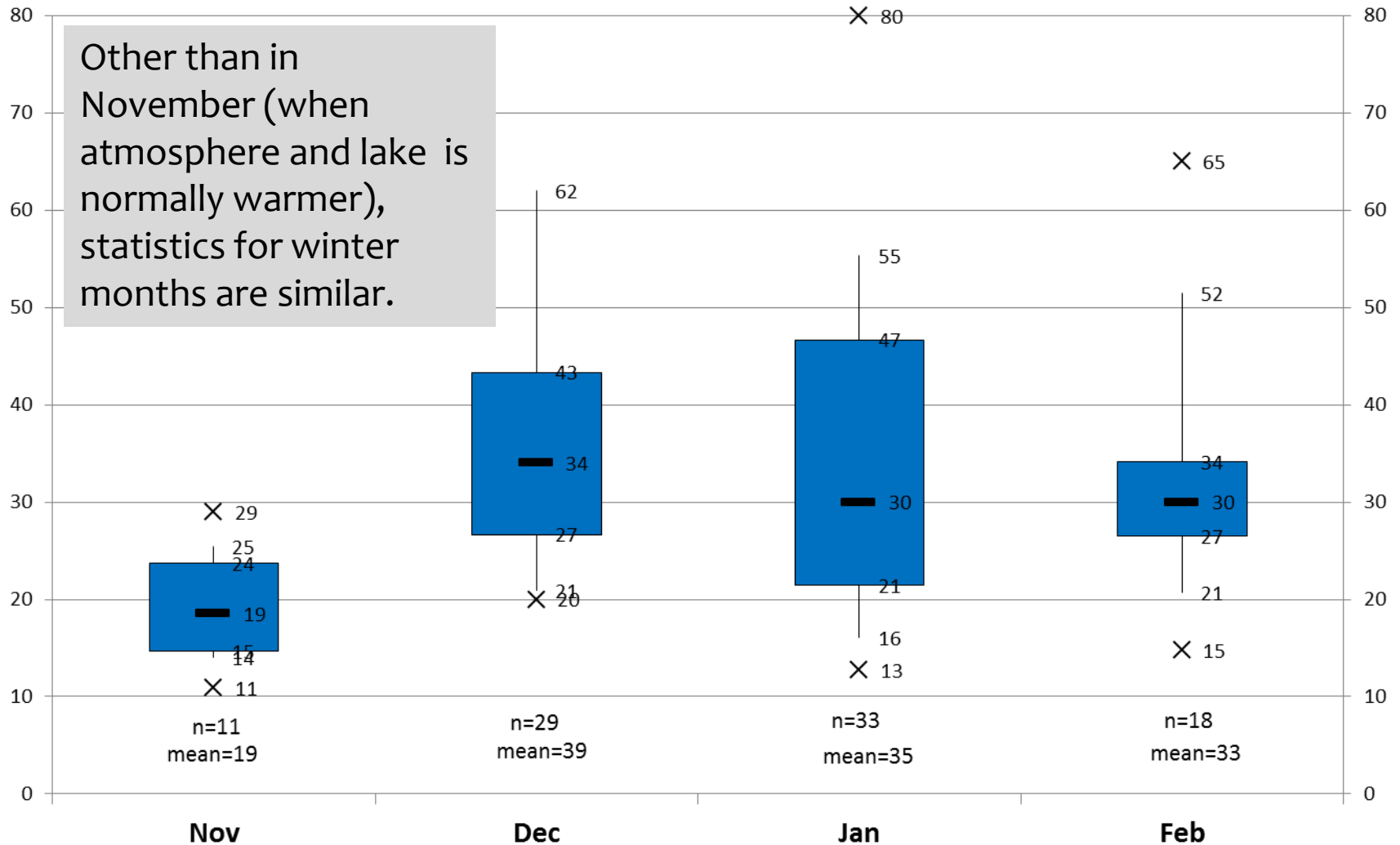
- LES sees a higher SLR value compared to other snows (by nearly 2X)
- However, LES also sees a significant interquartile range of values, with the 25th and 75th percentiles at 22 and 43 respectively
- LES SLRs are also positively skewed, suggesting that it is more likely for deviations to be above the median than below



Snow to Liquid Ratios (SLR) for NWS Marquette Per Month for LES Snowfall Events at least 1in/6hr



Solid Bar -- Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)

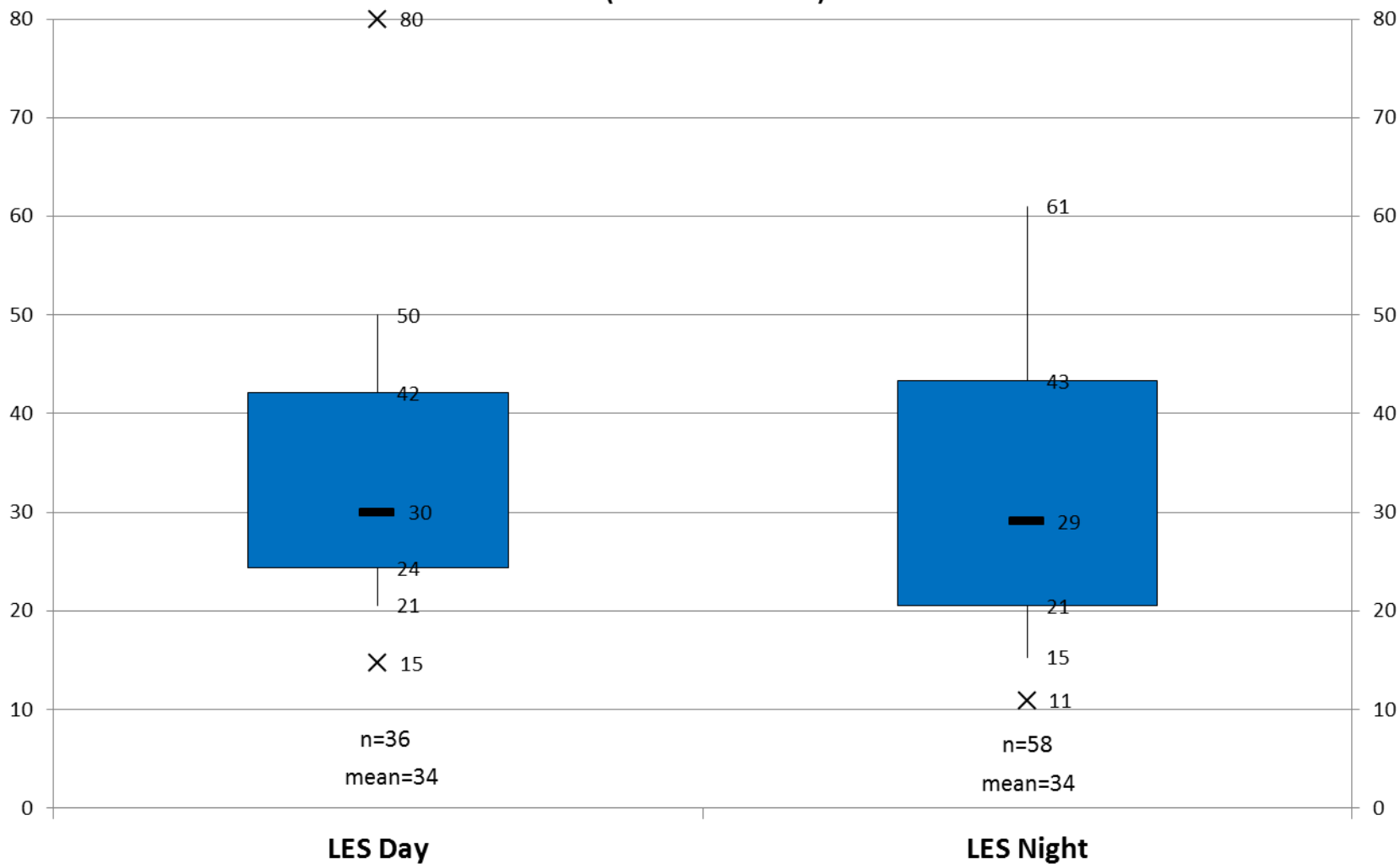




Snow to Liquid Ratios (SLR) for NWS Marquette for Daytime and Nighttime LES Snowfall Events at least 1in/6hr



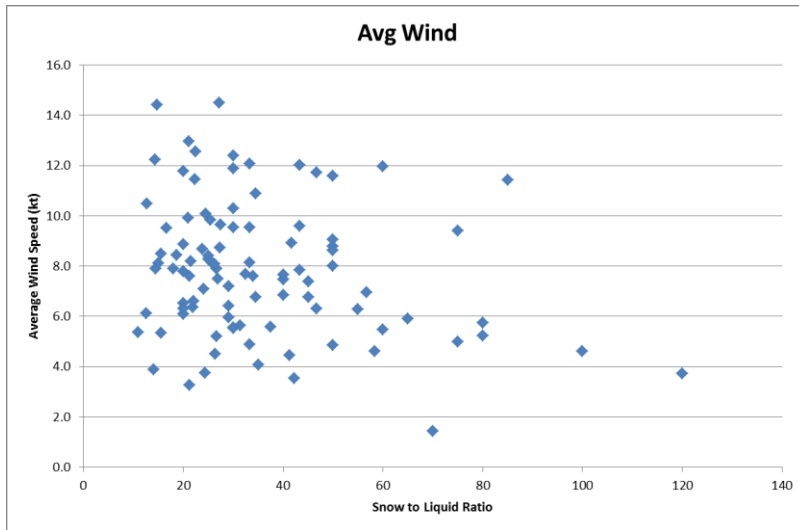
Solid Bar -- Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)



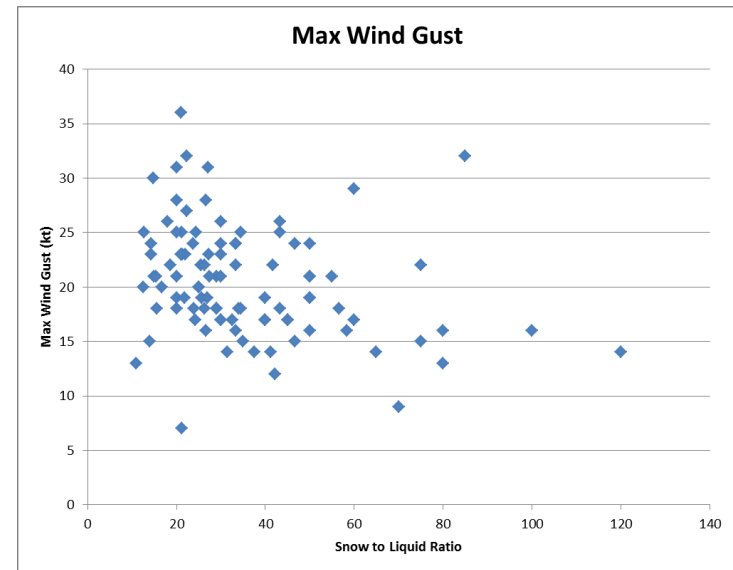
Does Surface Wind Play a role?

- Some evidence that confirms that higher wind speeds produce lower SLR due to collision and fracturing of snowflakes.
- Also seeing generally higher SLR values during lower wind speed situations.
- Could be seeing some of the siting errors come into play.

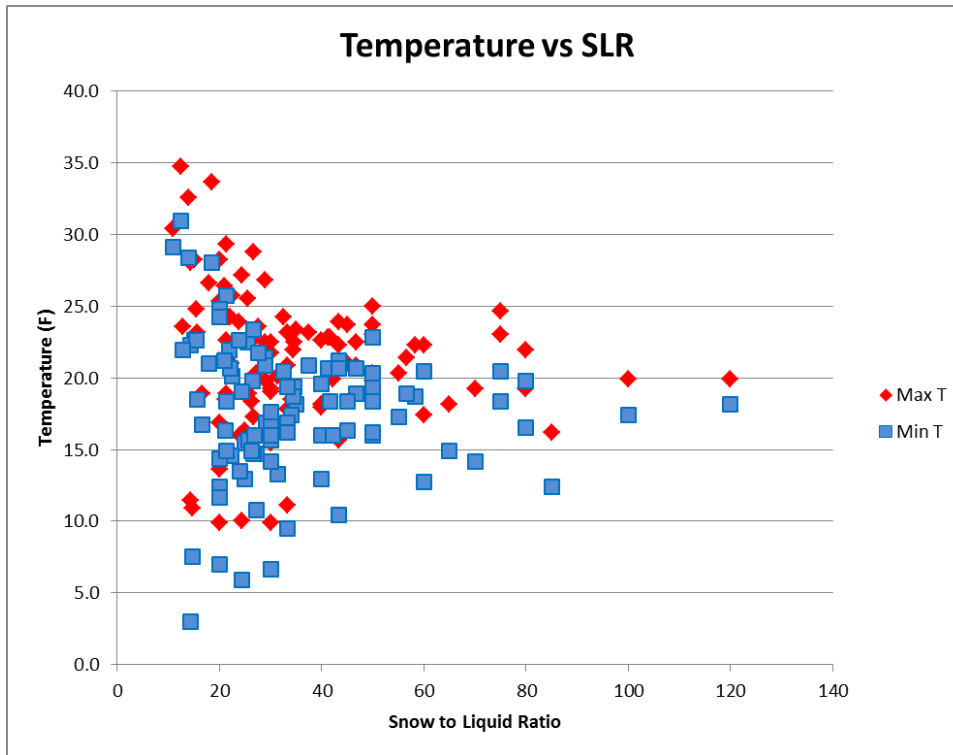
Average Wind vs. SLR



Max Wind Gust vs. SLR

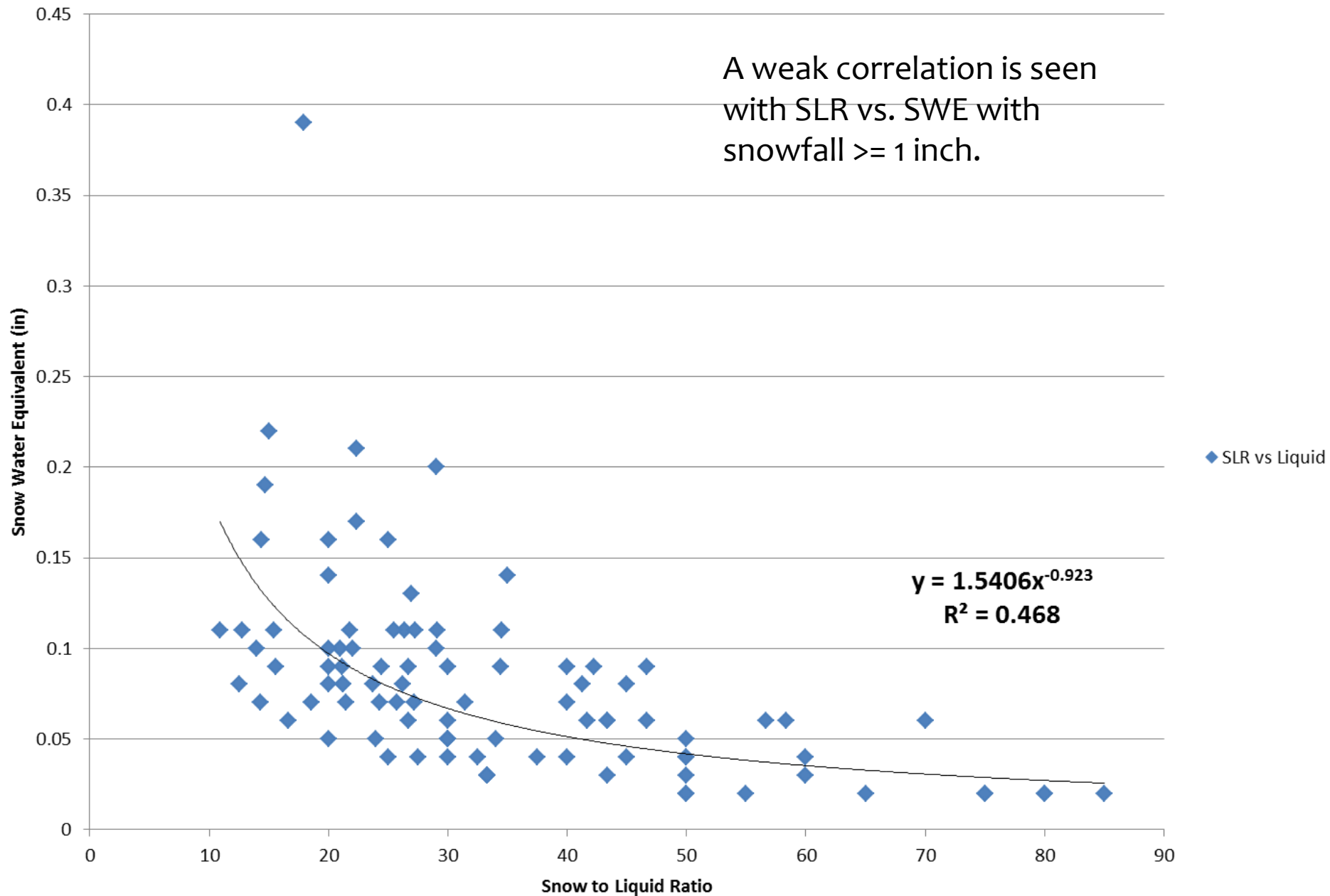


What about temperature?

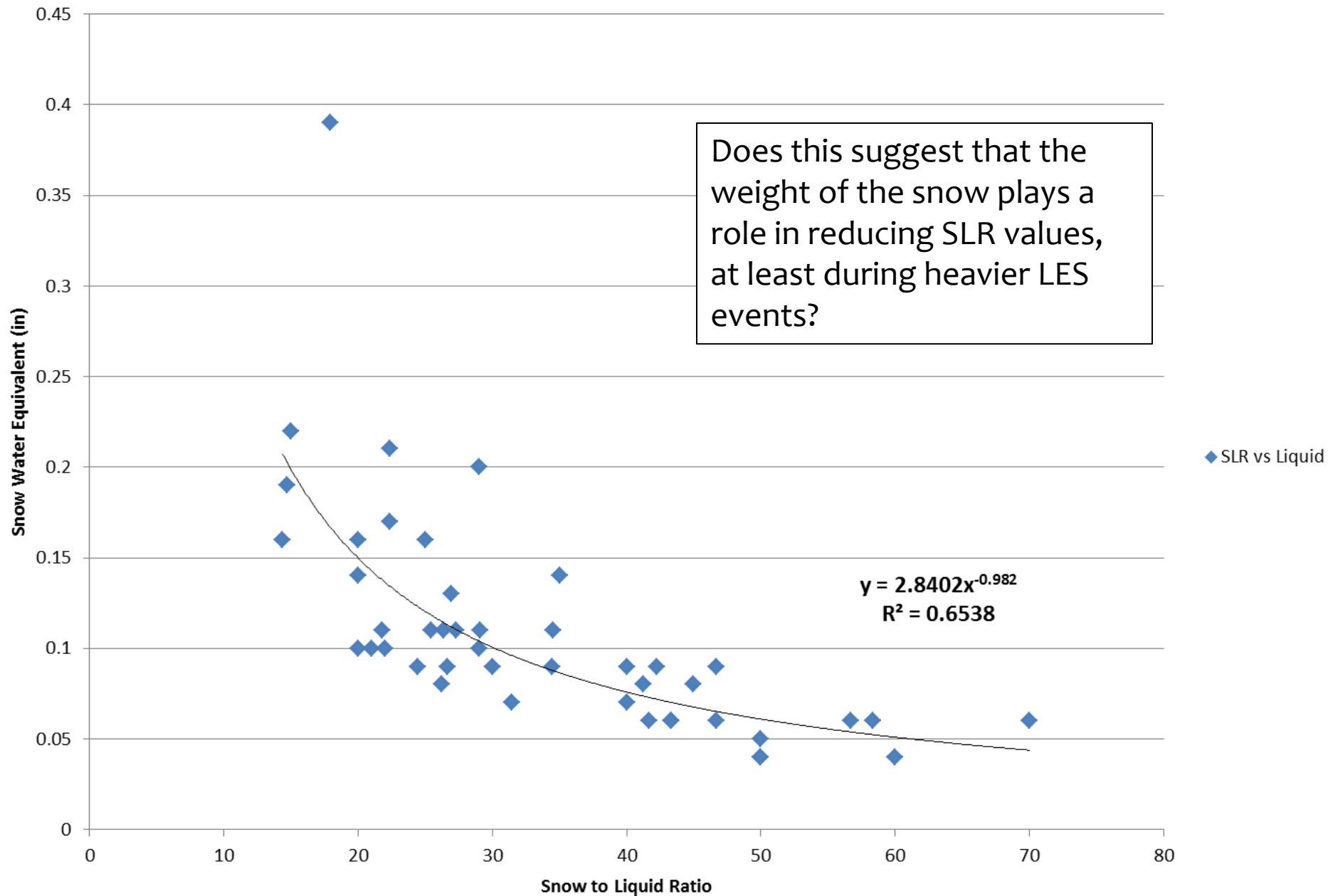


- * As seen by Roebber et al. (2003) and Dube (2003) in all snowfall cases, sfc temperatures also play a role in LES SLR values
- * For all max temperatures above 25F, the SLR is below 30
- * For all SLR values above 43, the temperature range was between 12 and 25 F

SLR vs Liquid for LES ≥ 1 in



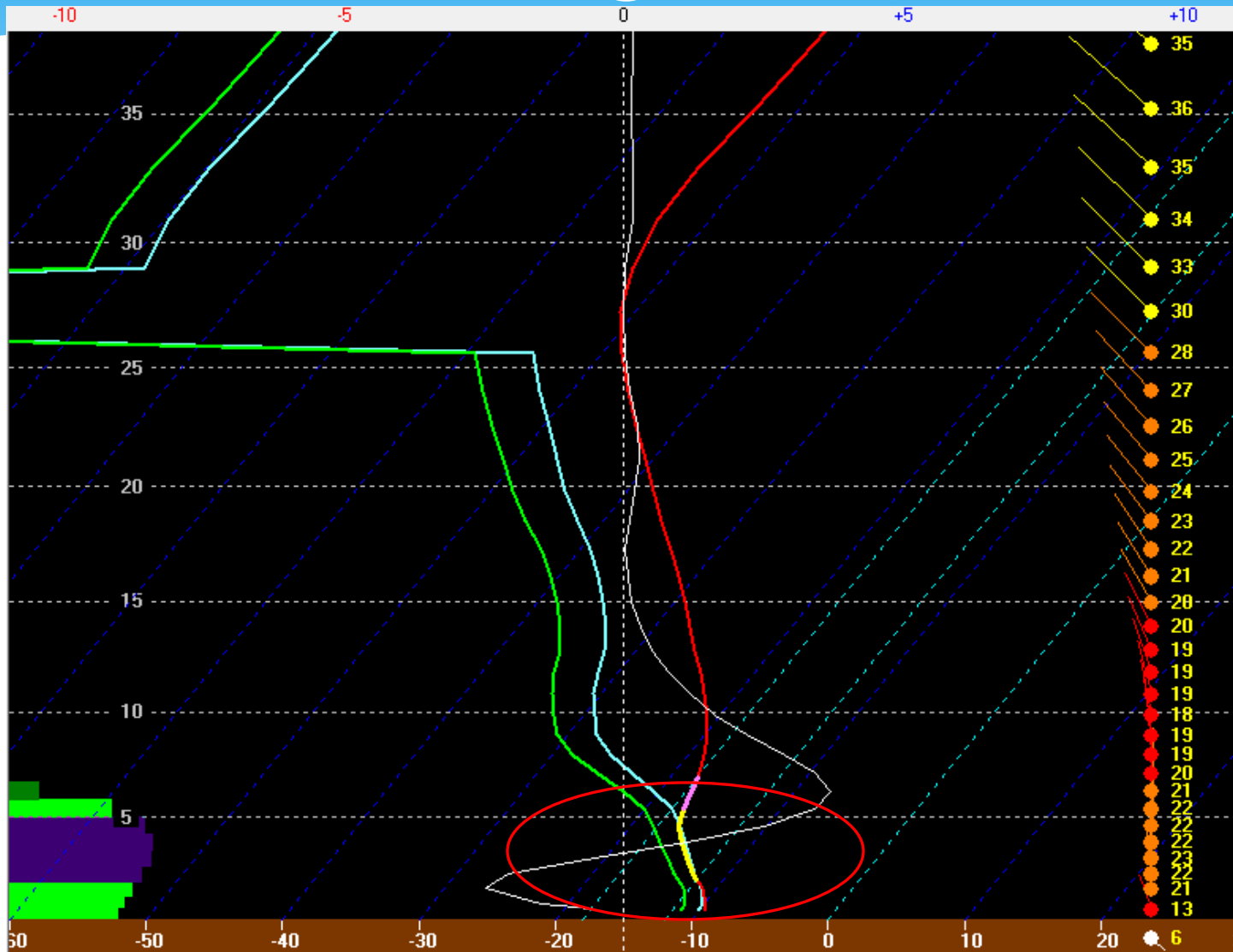
SLR vs Liquid for LES >= 2 in



Composite Soundings

- * RUC 00hr (analysis) sounding data (from BUFR files).
- * Sounding time was -3hr from time of snow and SWE observation
 - * Taken to best represent the entire period of observation.
- * Software for creating composite sounding data was developed by Andrew Just (NWS La Crosse, WI).

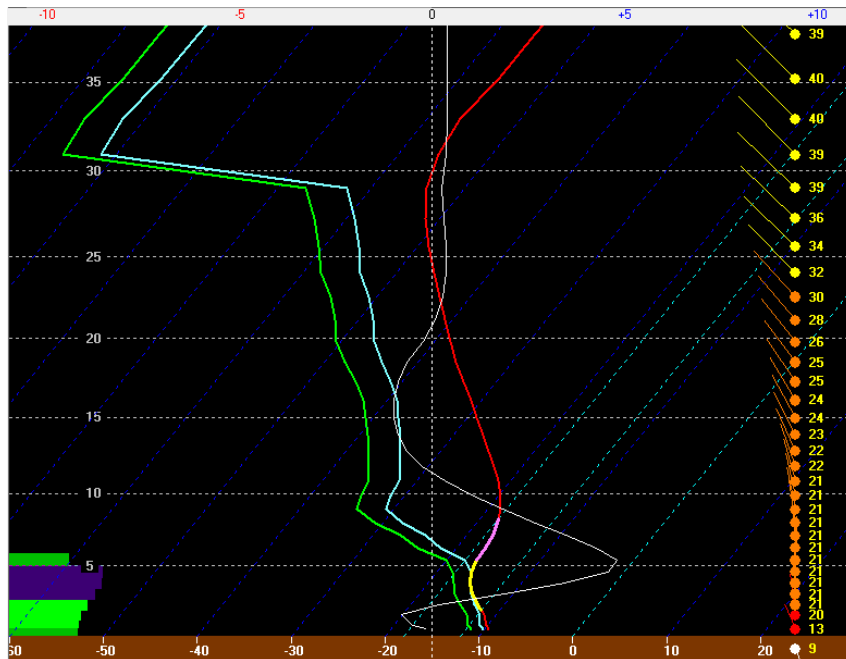
Composite Sounding for All LES (1 inch or greater)



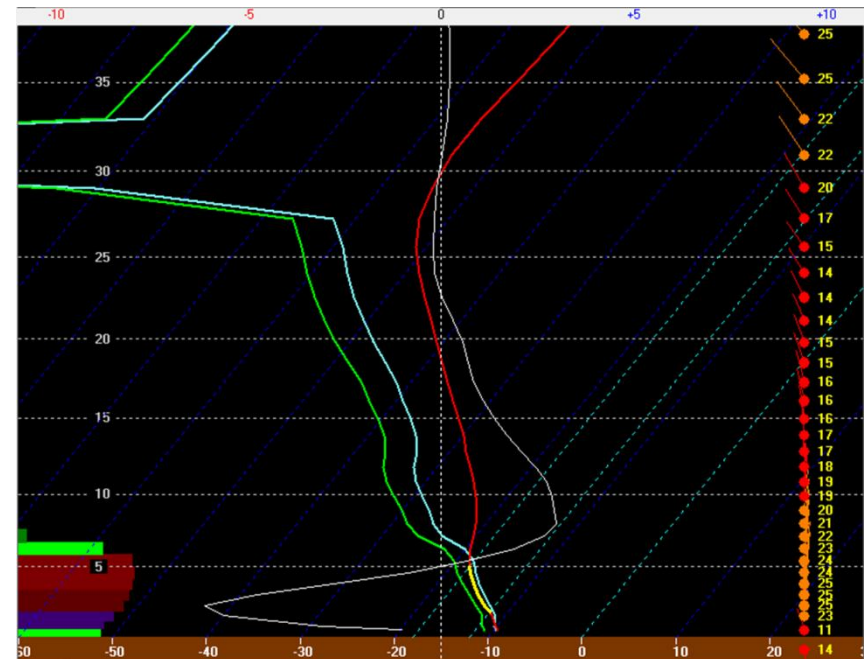
Composite Sounding for LES SLR Values

Not many obvious differences which will make it very difficult to forecast extreme SLR values in LES.

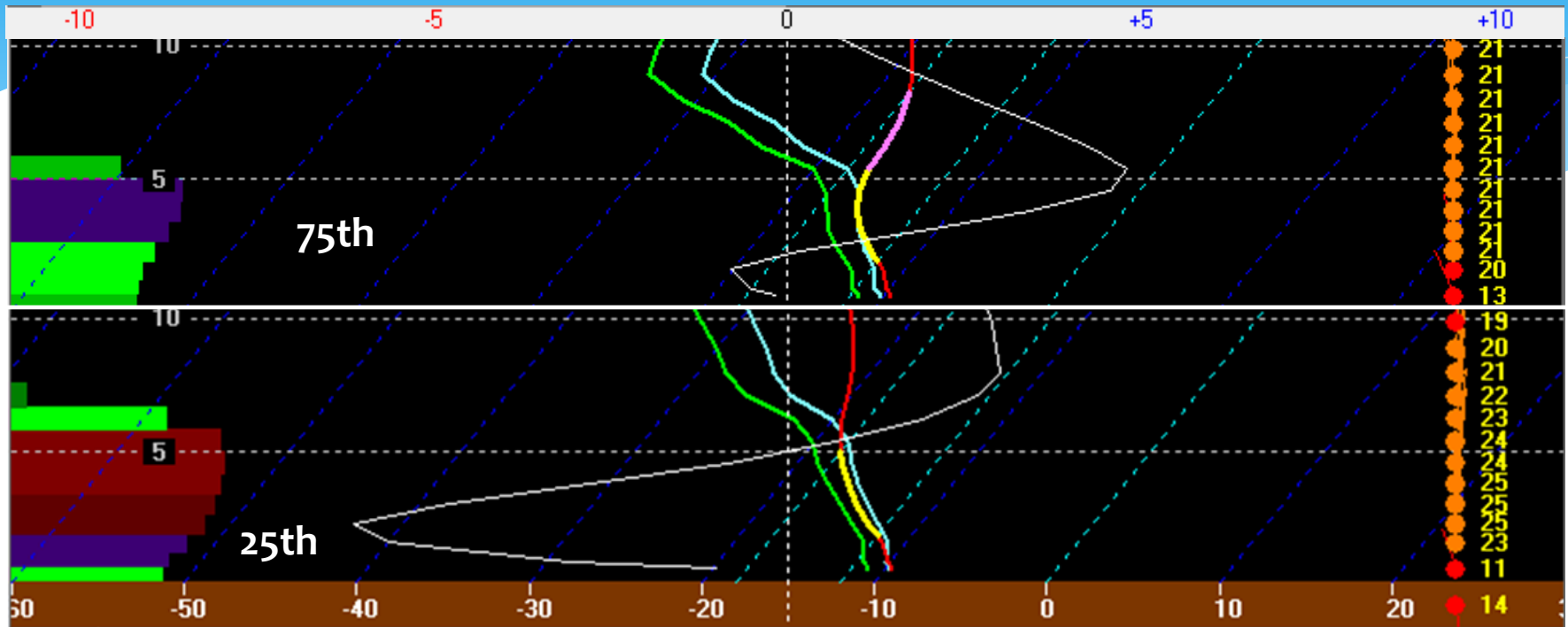
75th Percentile and above



25th Percentile and Below

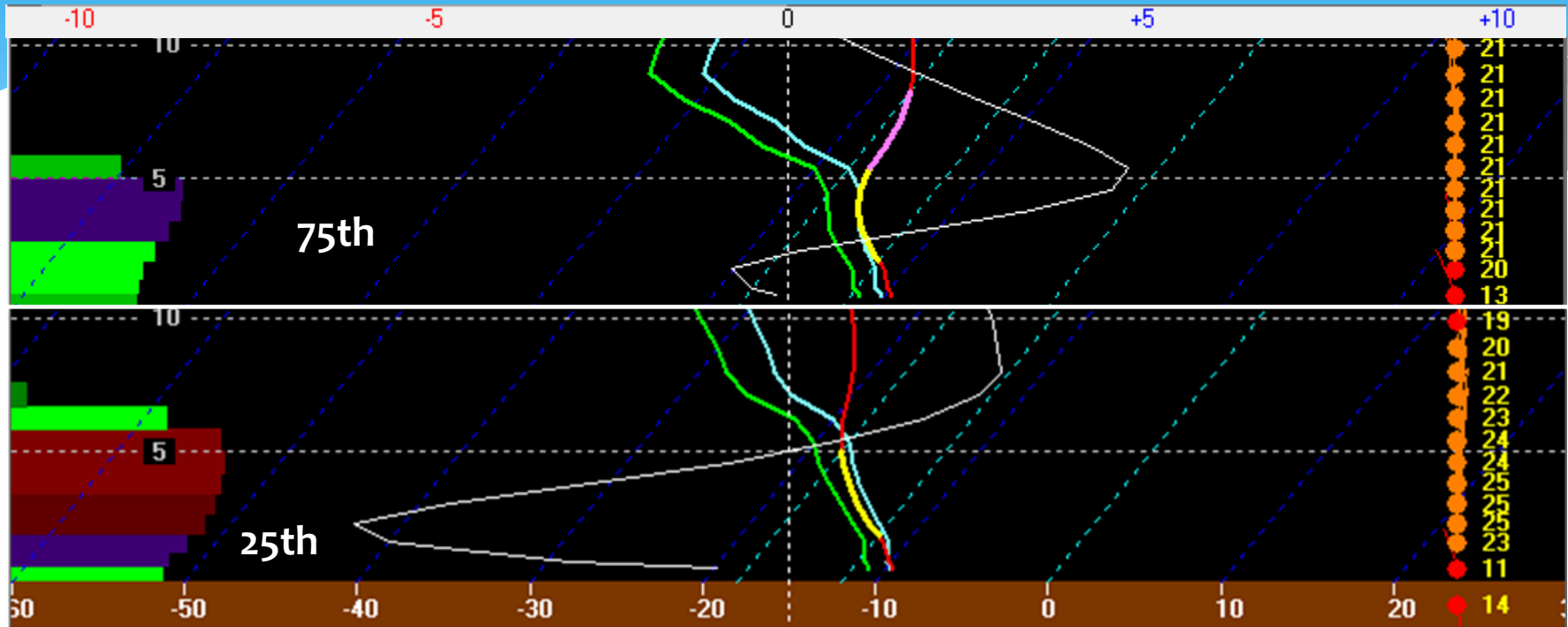


Composite Sounding for LES SLR Values

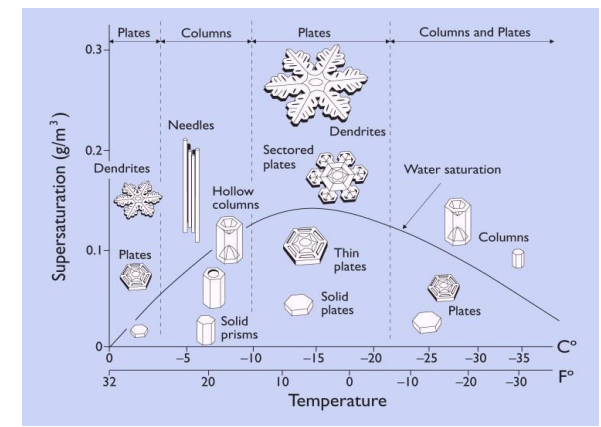


- Stronger/sharper inversion in higher SLR values. This allows a shallower convective BL, with most if not all of the cloud layer within the DGZ.
- Slightly less low level moisture in higher SLR values.
 - Possible less riming
- Similar Low Level Temperature
- Much stronger low level vertical motion in lower snow ratios.
 - This could be a signal of higher snow rates, thus causing reduced SLRs
 - Also, less riming with weaker vertical motion and less moisture (Jiusto and Weickmann 1973).
- Wind speeds are slightly stronger through the convective BL in lower SLRs (fracturing of snow crystals)

Composite Sounding for LES SLR Values

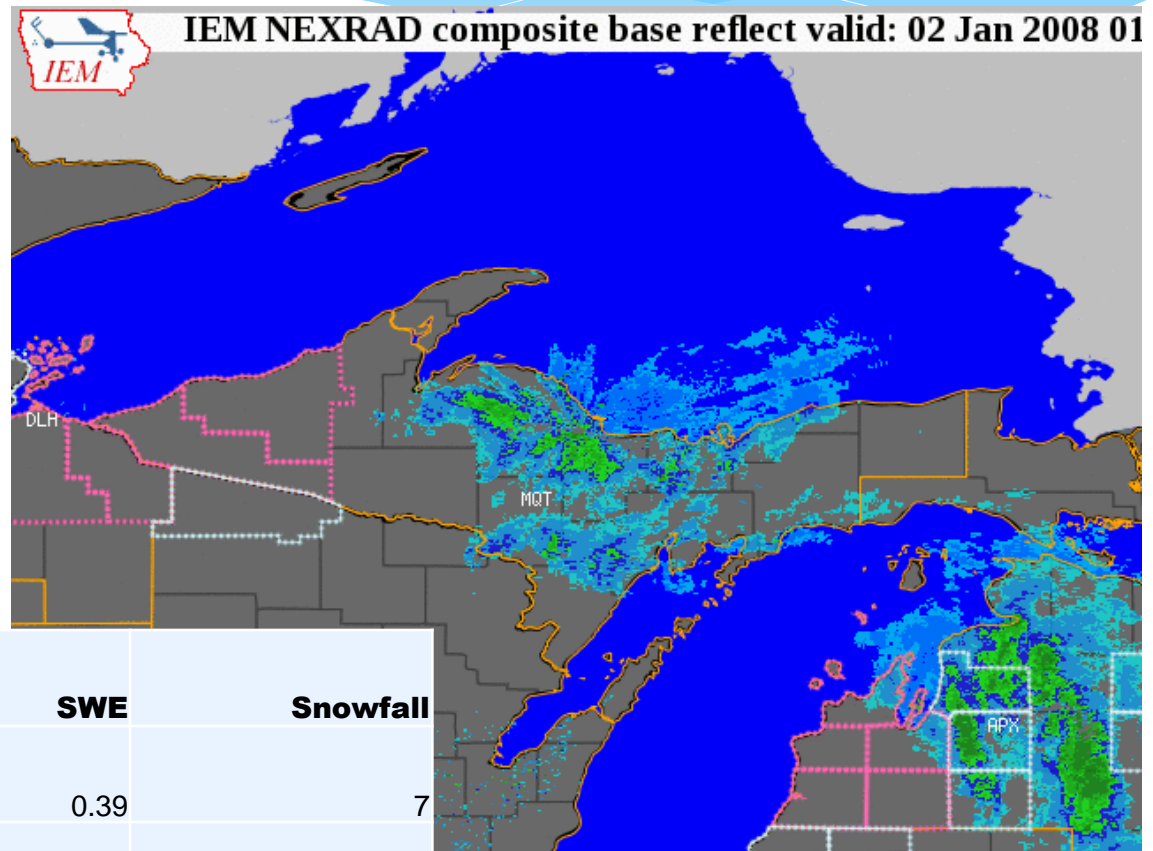


- Much stronger low level vertical motion in lower snow ratios.
 - Stronger Upslope Flow
 - Highest vertical motion likely below the DGZ
 - Could also be a signal of higher snow rates, thus causing reduced SLRs
 - Also, less riming with weaker vertical motion and less moisture (Jiusto and Weickmann 1973).



2008 Jan 02 LES Case

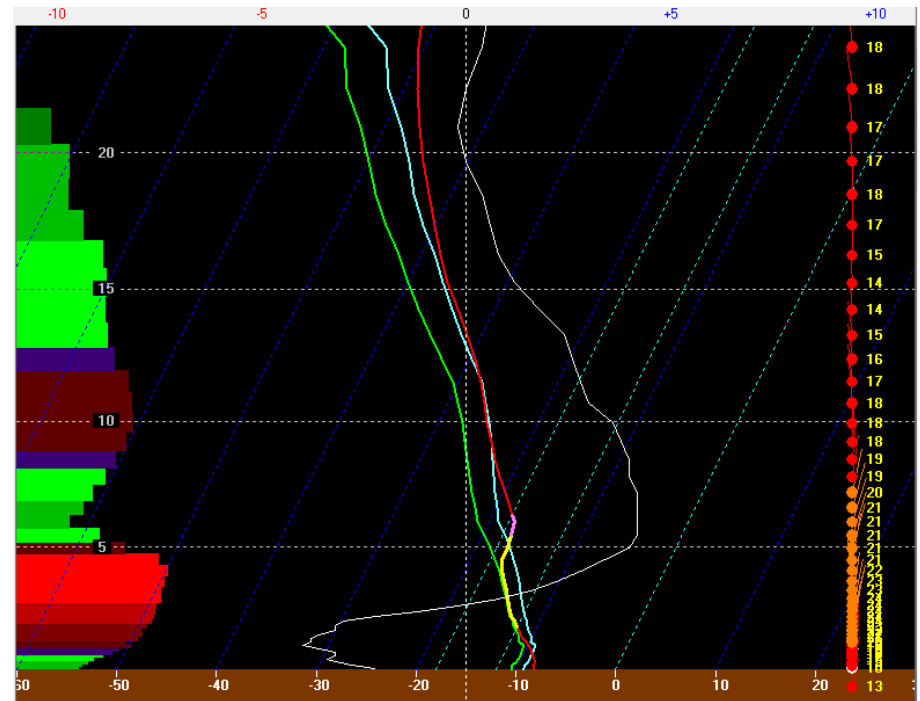
- * Generally a pure LES case with a wide range of SLR values
- * Over 10 inches of snow fell in 12 hr.



Date	Time	SLR	SWE	Snowfall
01/02/2008	0600	18	0.39	7
01/02/2008	1200	57	0.06	3.4

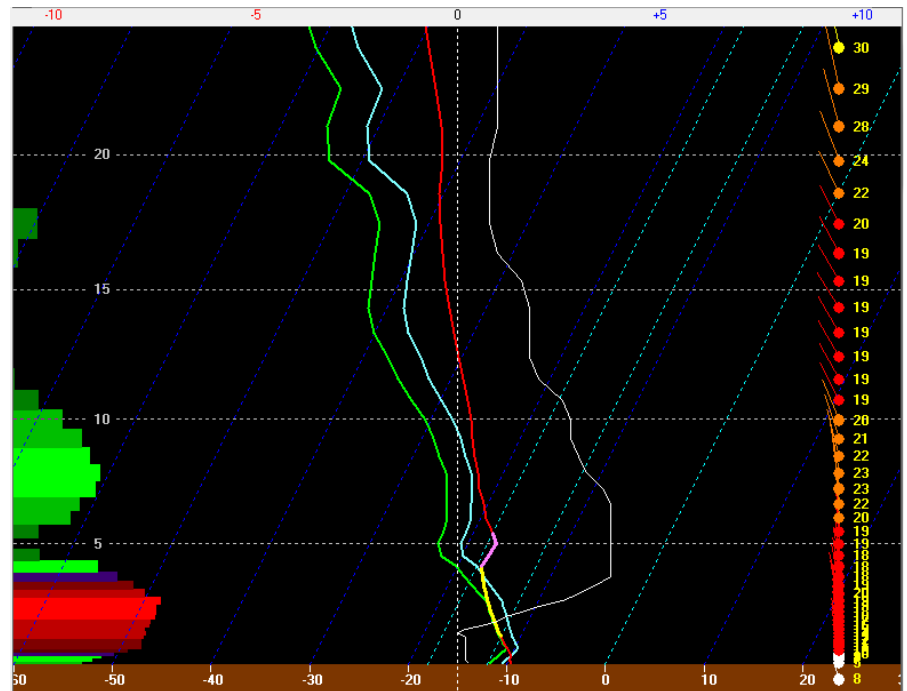
2008 Jan 02 00-06z

- * 7 inches of snow with 0.39 SWE → 27 SLR
- * Strong low level upward motion due to NNE flow.
- * Deep DGZ, but supersaturated aloft as well.
 - * Could see plates and columns in this area.
- * Stronger winds in convective boundary layer as well as near the surface



2008 Jan 02 06-12z

- * 3.4 inches with 0.06 SWE → 57 SLR
- * Weaker Upward Motion
- * Stronger Inversion with most of convective BL in the DGZ (despite the DGZ being smaller).



What does this mean for forecasting?

- * Intuitively, you would think that with such high snow ratios, we would consistently forecast snowfall too low.
 - * In fact, the opposite is true.
- * Forecasting QPF during LES is extremely challenging. We have better skill forecasting SnowAmt during pure LES cases.
- * I would recommend forecasting SnowAmt then converting to QPF using the appropriate snow ratio.
 - * Can still use QPF->SnowAmt for system or even enhanced snow.

Conclusions

- * Overall, LES events have higher SLR values compared to System and Enhanced Snowfall
 - * Positively skewed with a median of 30
- * LES SLRs tend to behave like previous climatological studies, however the interquartile range is much higher compared to other “types” of snow.

Conclusions

- * Composite Soundings do not immediately give a clear understanding of the physical/microphysical reasoning for higher vs. lower SLRs
 - * Thermodynamics are very similar
 - * Stronger low level omega may be a proxy for higher snowfall rates in lower SWE situations (heavier snow).
 - * Additional riming possible in these situations due to increased moisture as seen in composite sounding.
 - * Most of cloud layer within DGZ in higher SWE situations.
 - * Although more research is needed, you might expect lower SWE values (compared to the median) when forecasting LES events with strong low level upward vertical motion (single banded snow or strong upslope) vs. “light” snowfall associated with multibanded LES (weaker convective updrafts).

More work to do...

- * Retrieve more cases from 2001-2007.
- * Look more at the different LES types.
- * Retrieve more cases for other LES areas to eventually better understand LES SLR climatology across the Great Lakes.

Thank You

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References:

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Judson, Arthur, Nolan Doesken, 2000: Density of Freshly Fallen Snow in the Central Rocky Mountains. *Bull. Amer. Meteor. Soc.*, **81**, 1577–1587.

Roebber, Paul J., Sara L. Bruening, David M. Schultz, John V. Cortinas, 2003: Improving Snowfall Forecasting by Diagnosing Snow Density. *Wea. Forecasting*, **18**, 264–287.